Airvolt

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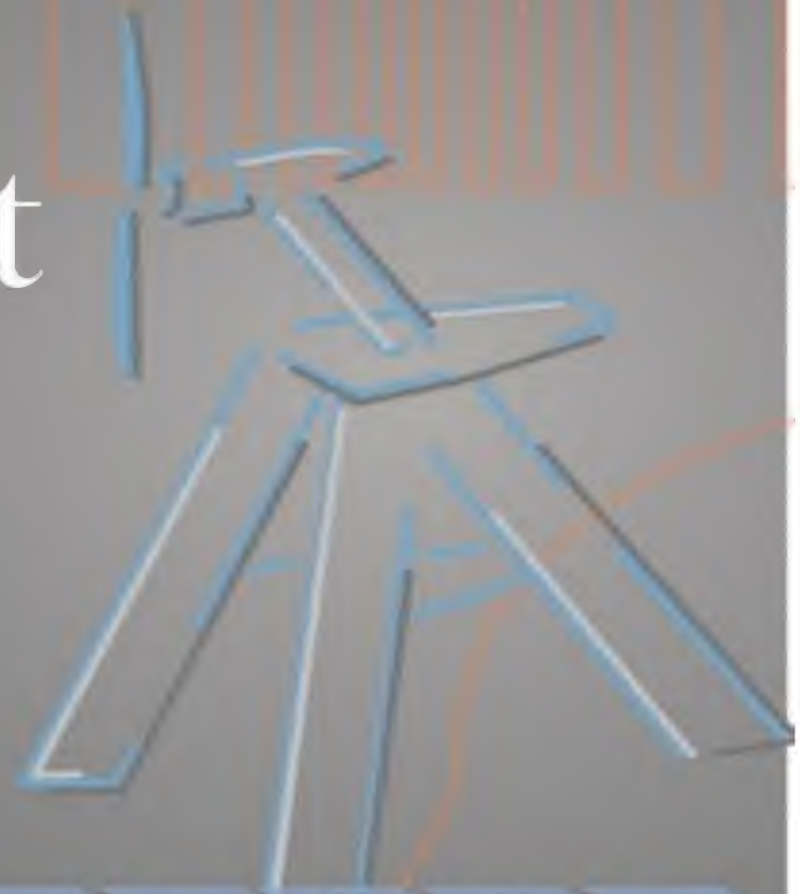
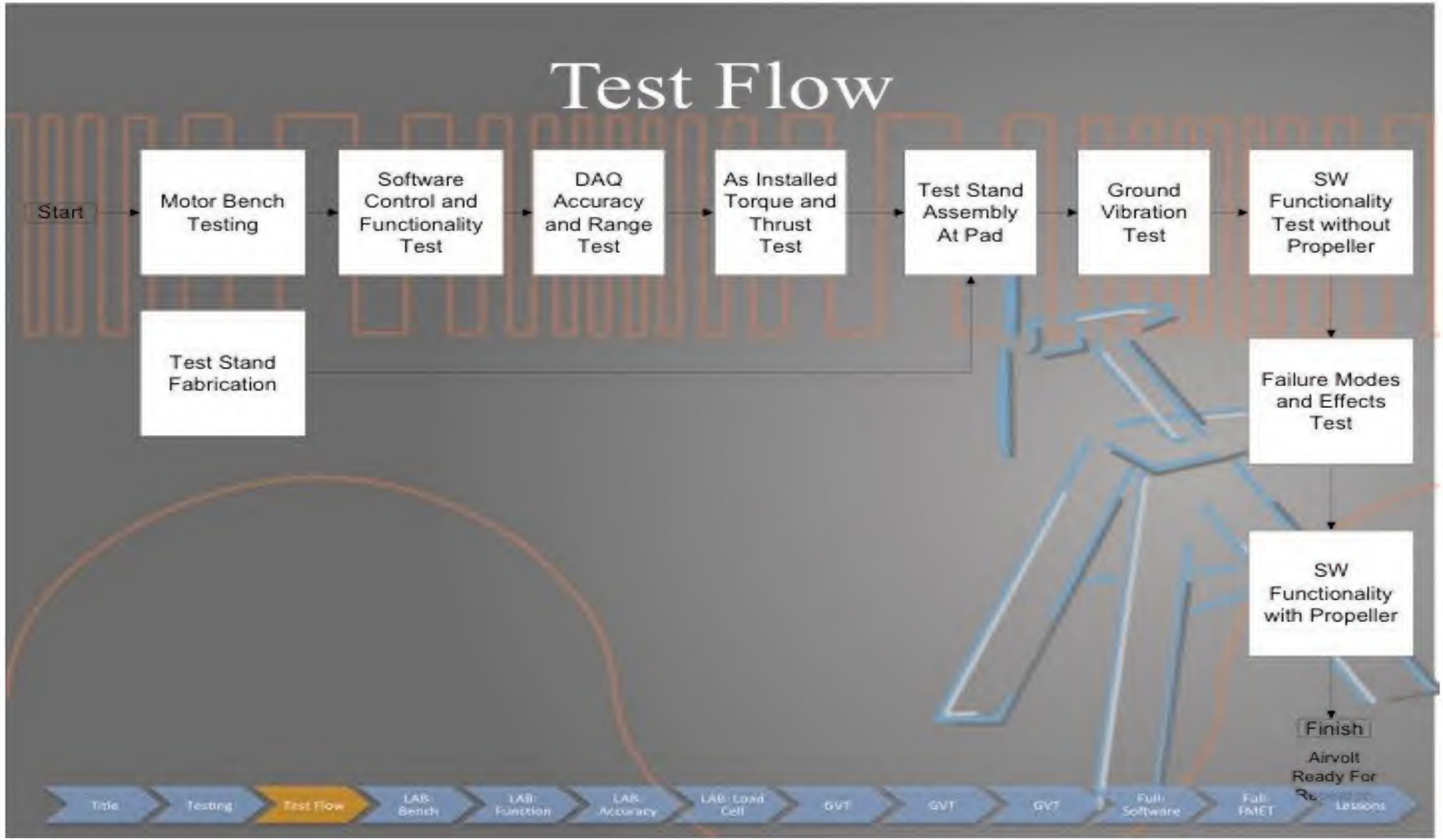


Testing

- Build Up Test Approach
  - Test often and integrate segments early
  - Use full length cables
  - Ensure best practices implemented and verified
    - Grounding/shielding
    - Calibration verification
    - Software/hardware integration
    - Structural modes
    - Manual safety, auto shutdown, software shutdown

Test Flow


Start
Motor Bench Testing
Software Control and Functionality Test
DAQ Accuracy and Range Test
As Installed Torque and Thrust Test
Test Stand Assembly At Pad
Ground Vibration Test
SW Functionality Test without Propeller
Test Stand Fabrication
Failure Modes and Effects Test
SW Functionality with Propeller
Finish
Airvolt Ready For
Title
Testing
Test Flow
LAB: Bench
LAB: Function
LAB: Accuracy
LAB: Load Cell
GVT
GVT
GVT
Full: Software
Full: FMET
Lessons

Bench Level Test

- Verify functionality
  - Control
  - Charging
- Better understand system

Software Control and Functionality

- Control with software
  - CAN Protocol
  - Test software command functions
    - RPM command
    - Canned profile
    - Built in Tests
- Utilizes full cable lengths
- Verifies sensors and their calibrations
- Lab hardware and software integration
  - Found issues with auto shutdown logic
- Gooseneck ground vibration/ping test with motor

DAQ Accuracy Test

- Verify each A/D channel is within requirement specifications
- Calibrator used to send test signal
  - Low, medium and high ranges tested
  - Air conditioner used
    - Temperature changes affect accuracy

Load Cell Test

- Verify installed configuration of thrust and load cell
  - Friction in thrust setup
  - Resulted in removing pillow block
    - Secondary support structure

Pad Testing: Ground Vibration Test

- Determine fundamental modes of structure
  - Data used to develop FEM model
  - Model can be used for new motor implementation

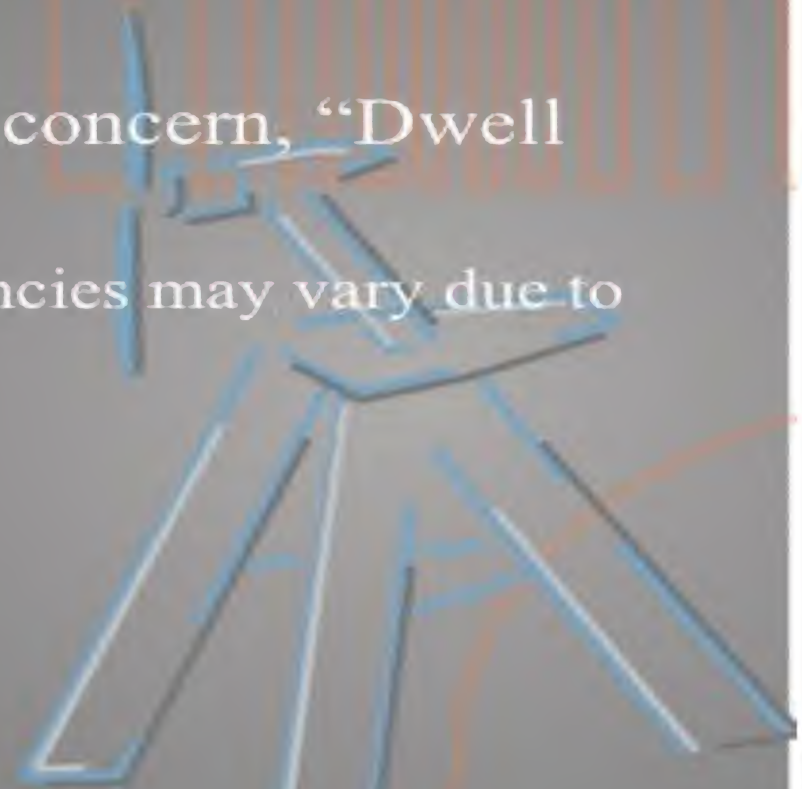
Ground Vibration Test

- Test Setup
  - GVT conducted outside
  - Rigid boundary condition - test stand bolted to concrete pad
  - 55 accelerometer locations, measuring 165 accel responses
  - 3 shaker excitations locations

Locations, Directions & Sensor Types		
● X, Y, or Z	Uniaxial, Endevco 7251A	
● X, Y, and Z	Triaxial, PCB T356A16	
● X, Y, or Z	Excitation (Shaker & Hammer)	

Ground Vibration Test

- Baseline Configuration Results
- Potential motor throttle settings of concern, "Dwell Keep Out Zone"
  - Motor throttle setting & GVT frequencies may vary due to propeller influence



Full Configuration Test

- With and without propeller
  - Use of control room
  - Identified EMI issues with propeller
    - Standard aircraft grounding and shielding processes implemented
    - More power draw
    - Data bias and noise
    - Affects auto shutdown
    - More testing underway to address/mitigate EMI issue

Title | Testing | Test Flow | LAB Bench | LAB Function | LAB Accuracy | LAB - Load Cell | GVT | GVT | GVT | Full Software | Full PMET | Lessons

Failure Modes and Effects Test

- Identify weaknesses or deficiencies
- Verify safety features
  - Emergency software shutdown
  - Manual shutoff
  - Loss of communication link
  - Loss of power/ Uninterruptable Power Supply endurance

Lessons Learned

- Early testing on bench level identified
  - Incorrect calibration
  - Shutdown logic implementation
  - Incorrect wiring
  - Load cell friction within setup/design
- Full configuration pad testing
  - Determine structural modes
  - Safety shutdown systems
  - EMI issues
- What would we have done differently?
  - Apply load on motor in bench configuration